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Analysis of Prey Selection in Black Skimmer, Rynchops niger, Adults and Chicks using Continuous Video Monitoring

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ANALYSIS OF PREY SELECTION IN BLACK SKIMMER, *Rynchops niger*, ADULTS AND CHICKS USING CONTINUOUS VIDEO MONITORING

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of

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Ruth A. Beck

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Dedication

To Kevin. Your "take the bull by the horns" and "live for today" mindset inspired me to take chances in my own life. I also admired your undying love for the environment and the organisms within it. Lastly, thank you for your humorous stories, antics, and jokes; they always picked me up when I was feeling down. I will miss you dearly. May I live my life as fully as you did yours.

To my parents, who supported and nurtured my love of biology from day one. Through my changing interests you have always been there for me. It is because of you that I have become a biologist today.

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A special thank you to John Rebar for emotional support throughout the entire process and for letting me drag him to all my field sites at all times of the day and night to assist with data collection and fence construction.

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ABSTRACT

The man-made south island of the I-64/Hampton Roads Bridge-Tunnel System in eastern Virginia is home to a 100-pair colony of Black Skimmers (*Rynchops niger*). Although this site is free of mammalian predators, protected from direct human disturbances, and located in close proximity to extensive feeding areas, reproductive success has been lower than at colonies located elsewhere in the region.

A previous study at the site suggested skimmer reproduction was being limited by food availability (Gordon *et al.* 2000). In Gordon's study dropped prey items were collected near nests and catalogued in order to determine the composition of prey items being brought to chicks. Using the dropped fish collection method, the proportions of prey items may be biased toward items rejected by chicks. Over 54 % of the chicks' diet in Gordon's study was Atlantic Needlefish (*Strongylura marina*). Needlefish are generally larger in size than other potential prey items such as *Fundulus* spp., Atlantic Menhaden (*Brevoortia Tyrannus*), and Bay Anchovy (*Anchoa mitchilli*) and therefore may be more likely to be rejected by chicks. A camera system was used to determine if there was any difference in prey composition using remote camera data compared to the dropped fish method.

During the approximate ten-week 2001 breeding season, a remote controlled high-resolution color and black/white CCD video camera equipped with zoom lens was use to continuously record feeding bouts from hatching to fledging

at selected nest sites (near-infrared camera sensitivity permitted excellent night observations with low power IR illuminators). Using prey composition and length, we then tested the hypothesis that adult Black Skimmers selected prey items of a certain size or species that was inappropriate for the age of the chick.

We found that prey composition differed greatly between the dropped fish method and the remote camera technique. Using remote camera data, it was determined that 48% of prey species were *Fundulus* spp. and only 10% Atlantic Needlefish compared to the 54% Atlantic Needlefish in 1999 (Gordon 2000). The overall rejection rate of prey items delivered to the nest was low (3%), but there was significantly more fish rejected within the first five days of a chick's development. Needlefish had the highest overall rejection rate compared to all other prey items, though it comprised only 5% of all the fish delivered to the chick during the first five days of development.

The size of prey items was found to be significantly smaller within the first five days of a chick's development, suggesting that adults selected smaller fish for younger chicks. In addition, the size of rejected fish was not significantly different from that of accepted fish. Therefore, the data do not support the hypothesis that adults selected prey of inappropriate size or species for the age of the chick.

ANALYSIS OF PREY SELECTION IN BLACK SKIMMER, *Rynchops niger*,

ADULTS AND CHICKS USING CONTINUOUS VIDEO MONITORING

INTRODUCTION

The Black Skimmer (*Rynchops niger*) is a colonially nesting waterbird, which has an almost entirely coastal breeding range. The skimmer's breeding range extends from Massachusetts to southern Mexico on the Atlantic Coast and from southern California to Mexico on the Pacific Coast (Gochfeld and Burger 1994). They prefer to nest on sparsely vegetated areas such as sand, gravel, or shell bars. Skimmers are also reported to nest on broad racks of dead vegetation on salt marshes (Burger and Gochfeld 1990). They are primarily fish-eating birds, though have been reported to eat shrimp in Georgia (Tomkins 1933). They are unique due to their bill; the lower mandible extends beyond the upper mandible. Skimmers feed by inserting their lower mandible slightly under the water during flight. When the bird detects an object it clasps down upon it. If the object is a potential prey item it can either be eaten by the adult in flight or brought back to the nest. Adult skimmers carry a single, whole prey item to the nest site and forage both during the day and night.

At present, loss of breeding habitat due to coastal development is the main factor affecting status the status of Black Skimmers in North America (Gochfeld and Burger 1994). The status of Black Skimmers on the East Coast ranges from endangered (NJ) to threatened (NY). Historically, the numbers of skimmer colonies on the East Coast has decreased considerably from the 1800's (Burger and Gochfeld 1990). Black Skimmer eggs were harvested in large numbers during the nineteenth century (Forbush 1925). The overall decrease in skimmer numbers on the East Coast may have resulted from the taking of skimmer eggs. In addition, the loss of preferred nesting associates such as terns, as a result of the millinery trade, may have contributed to a decrease in the skimmer population.

Studies on the East Coast have cited starvation as a primary cause of nestling mortality in colonies (Burger and Gochfeld 1990; Taylor 1997). A previous study at this site (Hampton Roads Bridge-Tunnel, Norfolk VA) suggested skimmer reproductive success was limited by food availability (Gordon et al. 2000). In that study, in order to determine the composition of prey items being brought to chicks, dropped prey items were collected near nests and catalogued.

Two separate approaches have been used to determine prey size and composition in colonial nesting birds. Several studies, such as Gordon et al. (2000), have focused on dropped prey items collected near nests (Courtney and Blokpoel 1980; Atwood and Kelly 1984; Loeffler 1996). In 2001, this general approach was not possible at this site because of the presence of nesting Laughing Gulls (*Larus atricilla*), which began nesting on the island in 1999 and have increased in number from 2 to more than 500 nesting pairs. Laughing Gulls quickly eat most of the prey items that are dropped in a nesting colony; therefore few dropped prey items were collected on the island during the 2000 and 2001 breeding seasons. Using the dropped fish collection method, the proportions of prey items may be biased toward rejected items. Black skimmer chicks are reported to reject a portion of the fish offered to them by adults (Quinn 1990).

Secondly, other studies have used direct observations of birds returning to the colony to determine prey length and species (Erwin 1977; Courtney and Blokpoel 1980; Lehtonen 1981; Bayer 1985; Quinn 1990; Bogliani et al. 1994; Ramos et al. 1998). All of these studies have been primarily limited to daylight hours. Since skimmers are known to feed nocturnally, nighttime observations are essential to fully understanding foraging behavior. During the 2001 breeding season we developed a new technique for determining size and type of prey over the entire 24-hour cycle.

For the approximate 10-week 2001 breeding season, a remote controlled high-resolution color and black/white Charged Coupled Device (CCD) video camera equipped with a zoom lens and infrared capabilities was introduced into the colony before the nesting season. The camera was used to continuously record feeding bouts at selected nest sites encompassing a 24-hour period from hatching to fledging. While stationary cameras have been used in several studies to determine the amount of predation on nests (Pietz and Granfors 2000; Ouchley et al. 1994), this is one of the few comprehensive studies using pan/tilt/zoom CCD cameras to monitor bird reproductive success and predation (Sykes et al. 1995). It is the first comprehensive study using continuous video to monitor several nests at one time, with a single camera. It is also the first study to record prey provisioning using 24-hour, continuous video monitoring for colonial nesting birds.

In the study by Gordon *et al.* (2000) 54 % of the chicks' diet was Atlantic Needlefish (*Strongylura marina*). In Virginia, such a high proportion of needlefish in Black Skimmer diets has not previously been reported in the literature (Erwin

1977). Needlefish are generally larger in size than other potential prey items such as *Fundulus* spp., Atlantic Menhaden (*Brevoortia Tyrannus*), and Bay Anchovy (*Anchoa mitchilli*) and therefore may be more likely to be rejected by chicks. As a result, this can erroneously inflate the proportion of collected prey items represented by needlefish. The camera system was used to determine if there was any difference in prey composition using remote camera data compared to the dropped fish method.

If the composition of prey items was in fact similar to that of Gordon's study (54% Atlantic Needlefish), adults may be delivering fish to the nest that cannot be consumed by the chick. Using prey composition and length, we tested the hypothesis that adult Black Skimmers selected prey items of a certain size or species that was inappropriate for the age of the chick. The fates of prey items brought to the nest were determined and their size was measured using the remote camera. Each prey item was then identified to species to determine the rejection rate of each individual prey species. There were two predictions; first we predicted that fish that are rejected by chicks would be larger than accepted fish. Secondly, we predicted that needlefish would be rejected more often than other prey species.

In addition to studying prey size and composition in Black Skimmer adults and chicks, we examined another research topic related to prey selection. The Birds of North America account for Black Skimmers includes several "Priorities for Future Research". In our study we examined two of the six listed priorities:

differential feeding by males and females and detailed analysis of nocturnal foraging behavior (Gochfeld and Burger 1994).

STUDY SITE

Numbers of skimmers on the Eastern Shore of Virginia have declined from more than 10,000 adults in 1977 to less than 1,700 adults in 2001 (Williams et al. 1998; R.A. Beck unpubl. data). Threats to nesting skimmers on the Virginia barrier islands include: 1) predation 2) flooding 3) rainstorms and 4) human disturbance. Although barrier beach habitat has been highly conserved on the eastern shore of Virginia, skimmers have sometimes been forced to use alternative nesting sites in other areas along the East Coast. Alternative sites tend to be dredge spoil islands (North Carolina), salt marshes, and rooftops.

An artificial man-made island which is part of the Hampton Roads Bridge-Tunnel in Norfolk, Virginia is one such alternative site. The Hampton Roads Bridge-Tunnel is part of the Interstate 64 highway system that connects Hampton, VA to Norfolk, VA. Two man-made islands support the tunnel that connects the two cities. The south island houses the tunnel maintenance and safety facility for the Bridge-Tunnel. This island is located at the mouth of the James River where it empties into the Chesapeake Bay (Figure 1). The bridge-tunnel system is managed by the Virginia Department of Transportation (VDOT, Hampton Roads District). An average of 100,000 cars a day passes through the tunnel during the summer season.

The island (Lat. 36° 55' N, Long. 76° 30' W) is 460m long and 215m wide and has been the site of a breeding colony of Black Skimmers for the past 20 years. The number of breeding pairs peaked at 350 in 1993 (Figure 2). In addition to

Figure 1 Arial View of Hampton Roads Bridge-Tunnel South Island, Hampton VA. No birds nest on the small island (Fort Wool) at the upper right corner of the photograph.

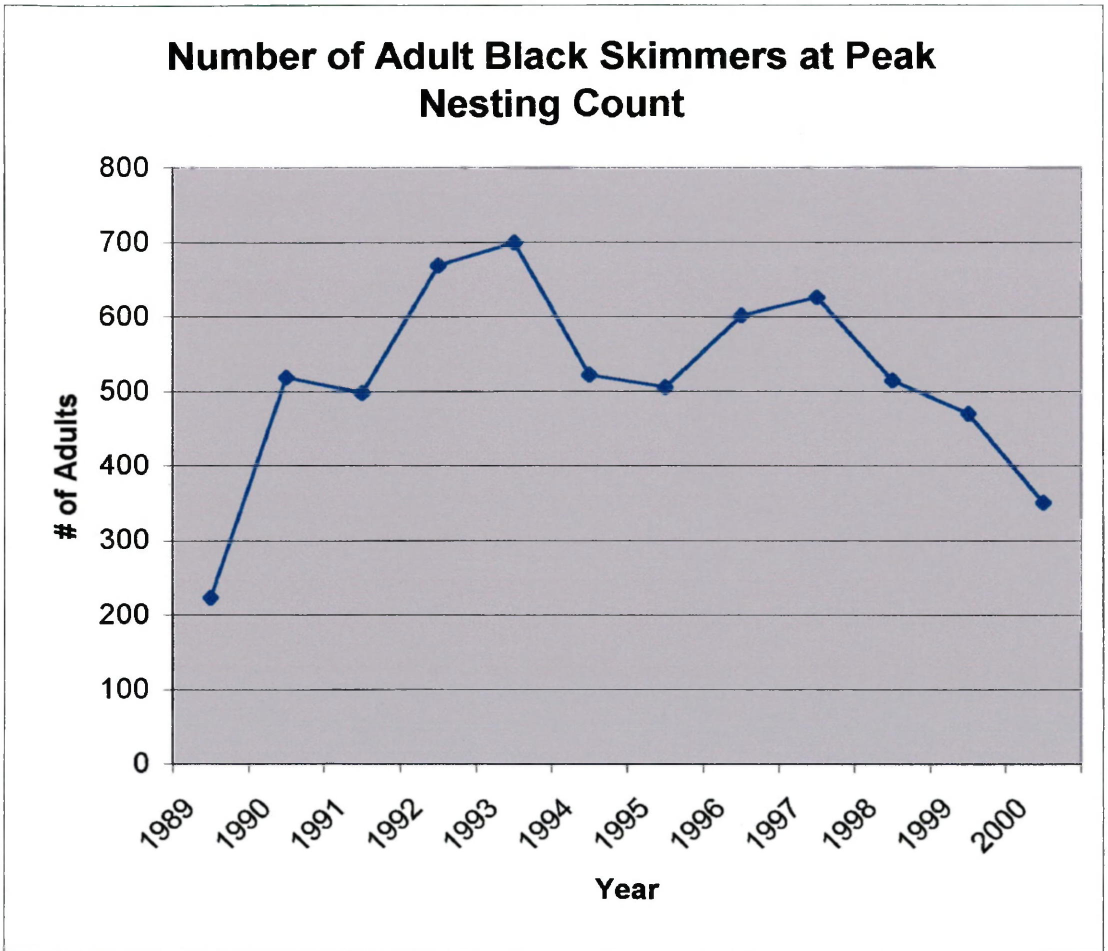

Figure 2 - Peak number of nesting Black Skimmers at Hampton Roads Bridge Tunnel South Island, Hampton Virginia. All observations made within the first 10 days of June each year. (R.A. Beck unpubl. data)

skimmers, the colony contains in excess of 3,000 pairs of Common Terns (*Sterna hirundo*), and up to 56 pairs of Gull-billed Terns (*Gelichelidon nilotica*).

In 1990 habitat at the south island was manipulated to determine the nesting preference of Black Skimmers. Vegetation was removed, by applying rock salt, from potential nesting areas of river bottom stone. It was found that adults preferred nesting in areas in which the vegetation had been removed (Keller 1992). A separate study at the island in 1993 found that while skimmers were more likely to nest in these areas of river bottom stone, 14% of eggs found in these areas were dented and 20% were broken (Matthews 1995).

In 1994 an experimental design was formulated to test the reproductive success of skimmers nesting on different substrates. Five plots each of sand, river bottom stone, and control (area left undisturbed) were prepared and monitored for reproductive success. After habitat manipulation, fewer than 1% of the eggs were dented in the sand, whereas 66.6% were dented in stone plots and 35% in the control plots. It was also found that skimmers preferred nesting on the edges rather than in the center of sand plots (Matthews 1995). Since 1995 strips of sand have been maintained during the nesting season in cooperation with VDOT personnel, Hampton Sheriff's Trustees, William and Mary students, Williamsburg Bird Club, and other volunteers (Figure 3).

With the bird population increasing rapidly, the existence of tern and skimmer colonies on the island became a public safety issue in 1992. Increasing numbers of young and adult birds were being killed as they wandered onto the

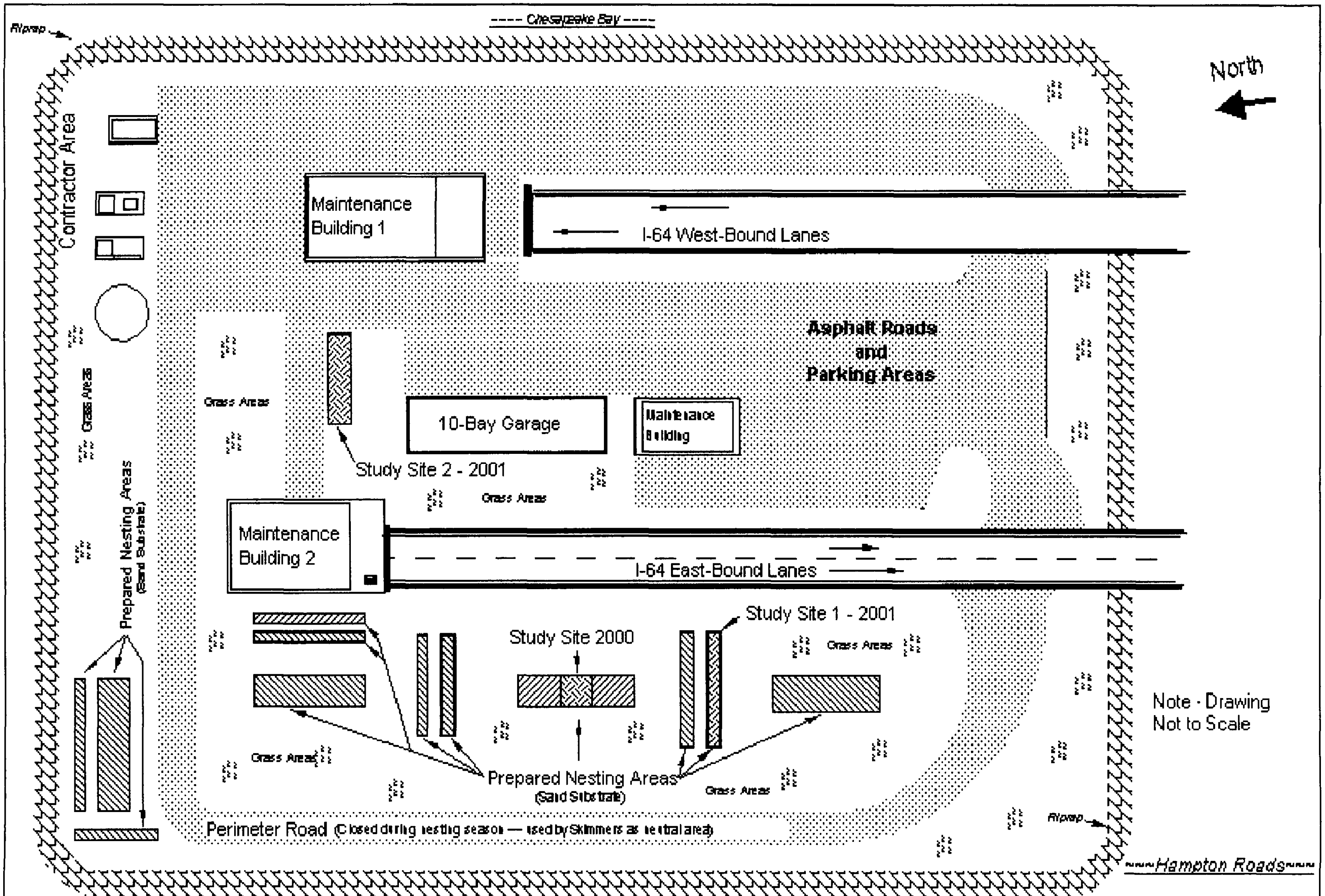

Figure 3 - Schematic Drawing of Hampton Roads Bridge-Tunnel South Island, Hampton Virginia.

highway and access roads. The recommendation was made to place temporary barriers, such as erosion cloth, around the boundary of the colony to reduce the number of birds in the roads (Keller 1992). Concrete barriers and erosion cloth fences were subsequently erected to keep adult and young birds from wandering outside the colony and entering the highway. In 1996 the Virginia Department of Transportation closed off the access roads to the nesting areas to all traffic from 1 April to 15 September (R.A. Beck pers. comm.).

This site is attractive to nesting skimmers and terns for several reasons: 1) minimal human disturbance 2) lack of mammalian predators 3) close proximity to extensive feeding areas 4) minimal flooding due to the higher elevation of the island (roughly 15 ft above mean sea level). Although the site appears favorable and attractive to skimmers, reproductive success has been less than expected in relation to colonies located elsewhere in the region (Gordon et al. 2000) (Table 1).

Table 1. Nest Success of East Coast Black Skimmer Colonies[1]

State	# Nests	# Eggs	% Hatched	% Fledged	# Chicks	Reference
NJ	—	—	—	—	.75	Burger and Gochfeld 1990
NJ	—	2.9	.43	—	.50	Burger and Gochfeld 1990
NY	190	3.7	.88	—	—	Safina and Burger 1983
NY	—	—	—	—	.65	Burger and Gochfeld 1990
SC	57	3.8	.35	.95	1.2	Blus and Stafford 1980
VA	110	3.55	.79	.11	.38	Erwin 1977
VA, MD	118	3.13	.53	.39	.58	Smith 1982
VA	180	3.04	—	—	.13	O'Connell 1992
HRBT-VA	252	2.92	.78	.54	.47	Gordon 1998
HRBT-VA	300	2.99	.36	.33	.35	Gordon 1997
HRBT-VA	261	2.88	.46	.30	.39	Matthews 1994
HRBT-VA	350	2.44	.23	.15	.09	Matthews 1993
HRBT-VA	31	2.10	.21	—	—	Keller 1992
HRBT-VA	27	3.00	.17	—	—	Keller 1991

[1]Information follows summary in Gordon et al. 2000.

METHODS AND MATERIALS

Video Monitoring 2000

Initial video recording of Black Skimmer nests was begun in early July and continued for one month during the 2000 breeding season using a stationary black and white CCD camera with a zoom lens. The camera was mounted approximately 6ft above the ground inside a wooden pedestal. The pedestal was then secured with sandbags. A wireless transmitter was used to route the camera signal to recording equipment held within a maintenance building. Two infrared lights (Provideo 82-2920) were attached to either side of the camera to enable nighttime observations.

Three consumer grade VCR's were used to record the output from the camera. VCR's were set to record at eight-hour intervals (10:00A - 6:00P, 6:00P - 2:00A, and 2:00A - 10:00A). Each VCR recorded on a 160-minute premium grade tape set to extended play. Tapes set on extended play record for a total of 8 hrs, therefore tapes needed to be changed only once per day. Each tape was encoded with the location, time, and date using a time/date stamp generator. The tapes were then cataloged for later review.

Video Monitoring 2001

Early during the 2001 breeding season continuous video observations of two nesting sites were conducted (Figure 3). The first site was monitored from 6 June to 17 July, the second 26 July to 15 August. A Panasonic CS-854 integrated CCD black & white/color camera with pan/tilt zoom capabilities was mounted on an eight foot 4'x 4' wood post approximately 15 feet from nesting skimmers before the nesting season began (Figure 4). This post was then embedded in a five gallon bucket of quick-crete, buried two feet underground, and stabilized by guide wires; this restricted the movement of the camera and prevented it from blowing over in high winds, which occur frequently at this site. The camera was also enclosed within an environmental housing, primarily to protect the camera from salt spray.

Two infrared lights (Provideo 82-2920) were attached to either side of the pole to enable nighttime observations. Metal shields were attached to each IR light to shut out incoming light to sensors, and thus extend the daily running time of the lights. The light emitted by the IR lights is invisible to the human naked eye and produced no observable effect on the behavior of the birds.

The signal from the camera was routed to recording equipment using less than 1,000 feet of RG58 cable. All recording equipment was housed in a secure location in the west vent building on the tunnel (Figure 3). A pan/tilt zoom remote controller was used to maneuver the camera. Specific camera locations were programmed into the controller corresponding to the location of nests. This allowed quick movement of the camera between nests. VCR recording was similar to that of 2000, see above, though recording times were changed slightly (7:00A - 3:00P, 3:00P - 11:00P, and 11:00P - 7:00A). Output from the camera was then displayed on a WV-CK 2020A Panasonic color monitor.

A.

B.

Figure 4 - A. Panasonic CS-854, Video Camera – 2001
B. Video Camera in Field in Environmental Housing

Site Preparation

In March of 2001 substrate in eight nesting areas was manipulated for nesting skimmers. Vegetation was removed from the plots and an even layer of sand 6-8 inches deep was applied at each site. Before Common Terns and Black Skimmers had arrived at the site, the colony was visited 3-4 times weekly at varying times during the night and day by a border collie to deter nesting Laughing Gulls. The site was walked from end to end until all Laughing Gulls were absent from the island for a period of at least 15 minutes. As the first Common Terns were sighted at the island use of the dog as deterrent was discontinued.

Video Processing

Once tapes were cataloged, they were processed using video capture. This allowed for a condensation of hundreds of hours of tapes into separate video clips of feeding bouts. This procedure captures small sections of videotape and saves them as analog form, computer files. Tapes were played on a VCR until a feeding bout was observed. The video output of a small segment of tape surrounding the feeding bout was then sent to a video capture program, VideoWave 4, via a video capture card and converted to analog form (AVI files).

Since AVI movie files tend to be very large in size (10,000 - 80,000KB), segments were saved as compressed, high quality, MPEG-2 files. These files were then replayed, paused, and slowed down by playing them on the VideoWave 4 capture program or Windows Media Player in order to gather specific data from the clips.

Data collected from the video clips included: date, time, nest, sex of adult, chick order, fate of prey at nest, prey species, handling time, and species of prey. Created files, that included all observed feeding bouts, were temporarily stored on a 40 GB external hard drive and then transferred to a CD using a CD Writer/Rewriter.

Observation of Feeding Bouts

Nests were observed continuously across 58 days. In the first nesting area 16 nests were initiated from which 17 chicks hatched; in the second nesting area 12 nests were initiated from which 3 chicks hatched. During the hours an observer was present the camera was placed on all visible nests within the plot area; during night hours only nests within the view of the IR lights were observed. The camera was pulled back to give an overview of the nesting area and zoomed in on a specific nest when an adult was observed entering the plot with a prey item. When the observers were away from the site video observations continued and the camera was set on a specific nest or set of nests.

Day vs. Night Observations/Tidal Influence

Video observations were separated into day, night, dawn, and dusk categories using sunset and sunrise data (Edwards 2001). Dawn and dusk were categorized as the 45-minute time period before and after sunrise and sunset, respectively. Low and high tides were obtained from The National Oceanic and Atmospheric Administration (Pentcheff 2001). The time of feeding bouts was compared to the low and high tides to determine when in the tide cycle they had occurred.

Prey Availability/ Fate of Prey

Prey species were identified by viewing feeding bouts from the video recordings of nests. All prey items were classified to species level when possible using "Peterson's Guide to Atlantic Coast Fishes" (Robins et al. 1986). Each prey item brought to the nest was classified as: accepted by chick, parent ate prey item (fish not offered to chick), parent flew away with prey item (fish not offered to chick), chick rejected prey item (left on ground), or prey item stolen before offered to chick. Rejected prey items were further analyzed to determine size, species, and at what stage of the chick's development the rejection occurred.

Feeding Rates

Feeding rates (prey items eaten by young/hour) were calculated at all nests using all feedings observed over the entire recording period. Feeding rates were also compared for day, night, dawn, and dusk observation hours for each nest. Feeding rates were compared between nests with 0, 1, or 2 chicks fledged at the end of the nesting season. The age at death of each individual chick was plotted against the average feeding rate, during the first five days of development, for each chick.

Prey Length and Biomass

Length and biomass of prey items were determined by first comparing the length of prey to the adult bill size. Initially, the gape lengths of skimmer study skins were measured at the Smithsonian Museum of Natural History in Washington, DC. Calibrated calipers were used to take all measurements. In skimmers, the lower mandible extends beyond the upper mandible; therefore both were measured to determine which is less variable. Adult skimmers are sexually dimorphic, the male being slightly larger in size and having a larger bill than the female. Measurements were taken for both males and females. The bill size of 75 skimmers collected in the United States was used for the final analysis, to give the most accurate estimation of bill length.

In order to determine the length of prey items shown on the videotapes, the sex of the adult skimmer was first identified, then the length of the prey item was recorded as a percentage of the upper (least variable) mandible. This percentage was multiplied by the average length of the upper mandible of the appropriate sex to estimate the size of the prey item.

Length-weight formulas were used to determine the biomass of prey species being fed to young (Meredith and Lotrich 1979; Durbin et al. 1983; Newberger and Houde 1995; Kasim et al. 1996). Biomass/chick/hour was calculated for all nests. Biomass/chick/hour was then compared between nests with 0, 1, or 2 chicks fledged at the end of the nesting season.

Monitoring Productivity

From 11 May to 30 August, Black Skimmer nests, eggs, and hatchlings were monitored by weekly visits to each nest throughout the nesting season. Young were considered fledged if they survived to 21 days, at which age they are able to fly. The Mayfield Method, based on the number of days each nest was observed, was used to estimate nest success (Mayfield 1961; Mayfield 1975).

RESULTS

Observation of Feeding Bouts

For the 2001 nesting season a total of 662 feeding bouts were observed for both of the sites monitored by video. Nests were observed for a total of 702.8 usable (chicks within camera sight) hours of tape. Numbers of observation hours were variable for each nest, from 3.6-261.4 hours/nest. Approximately 200 videotapes were used for the two plots over the nesting season.

Day vs. Night Observations/Tidal Influence

Daytime observations consisted of 519.9 hours while nighttime observations consisted of 182.9 hours. While there were no significant differences in overall delivery of fish between males and females during the nesting season (Figure 5), there were differences at night between male and female delivery with females bringing in significantly more prey items (Figure 6; Chi-Square, n=301, $X^2=4.1$, df=1, $p<0.05$). Females also delivered fish at a significantly higher rate than males during the first five days of development (Figure 7; Mann-Whitney U=10850.0, $p<0.01$). The overall delivery rate of prey items was significantly higher at night than during day, dawn, or dusk (Figure 8; n=39, Kruskal-Wallis, $X^2=10.0$, df=3, $p<0.05$).

More fish were delivered to the colony by skimmers during the high tide, combining day and night observations (Figure 9; n=662, Chi-Square, $X^2=4.1$, df=1, $p<0.05$). When taking into consideration only night observations the relationship was also significant (Figure 10; n=319, Chi-Square, $X^2=8.2$, df=1, $p<0.01$).

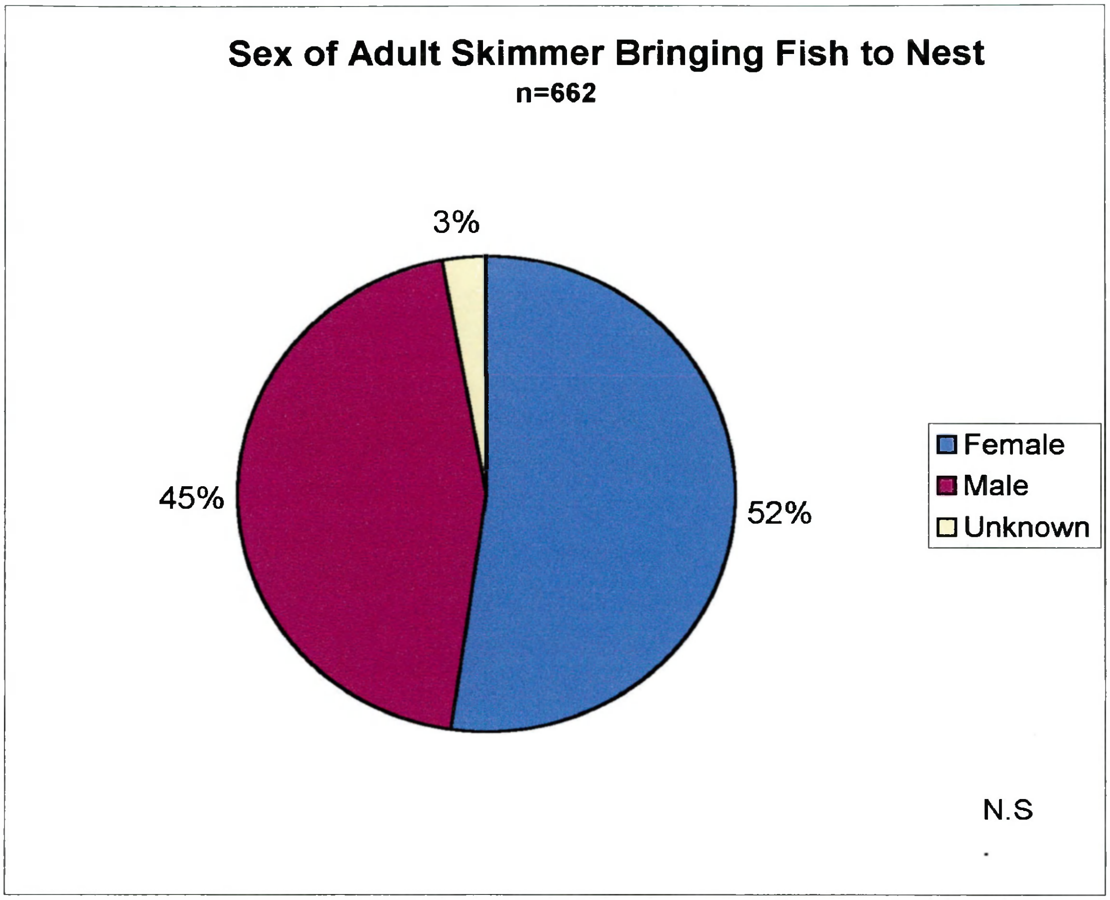

Figure 5 – **Sex of adult delivering fish to nest over the entire 24 hour cycle during the entire life of the chick. Difference between sexes was not significant.**

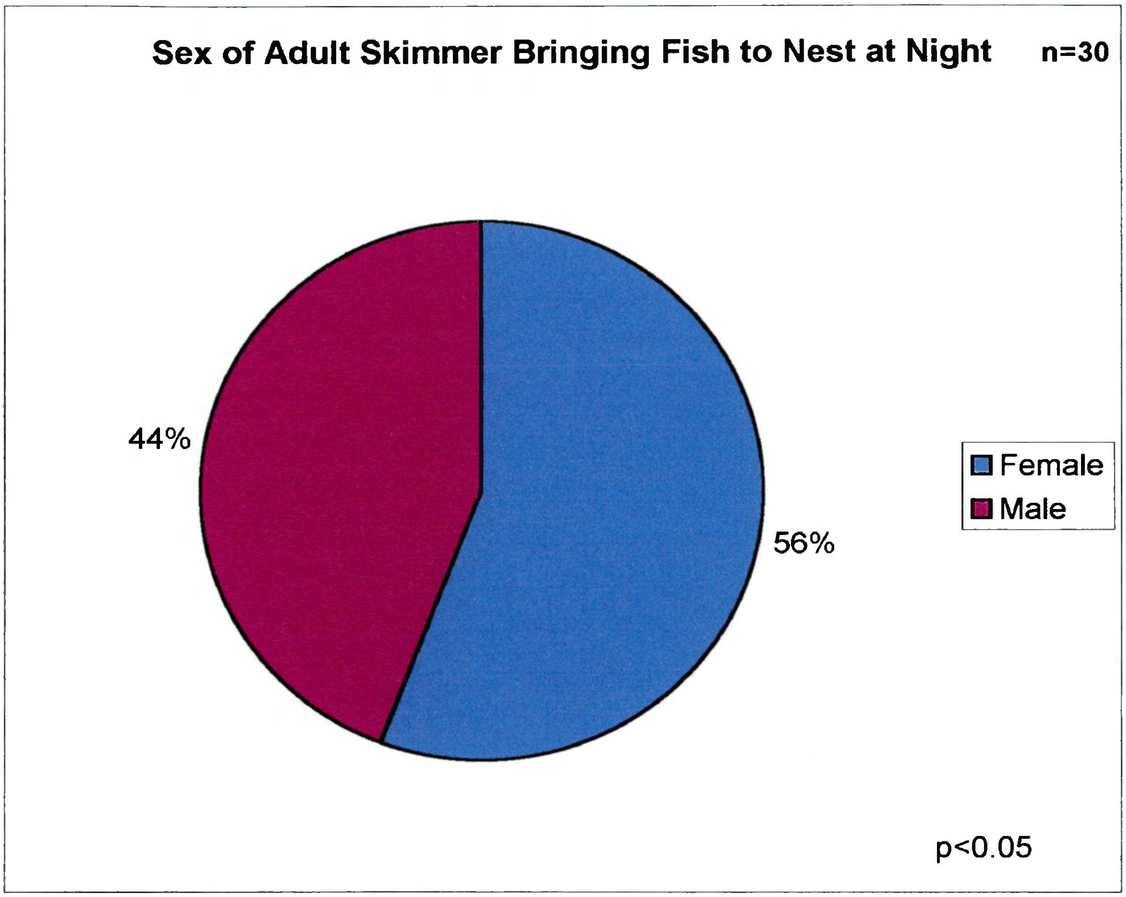

Figure 6 – Sex of adult delivering prey to nest at night during the entire life of the chick. Difference between sexes was statistically significant at the $p<0.05$ level.

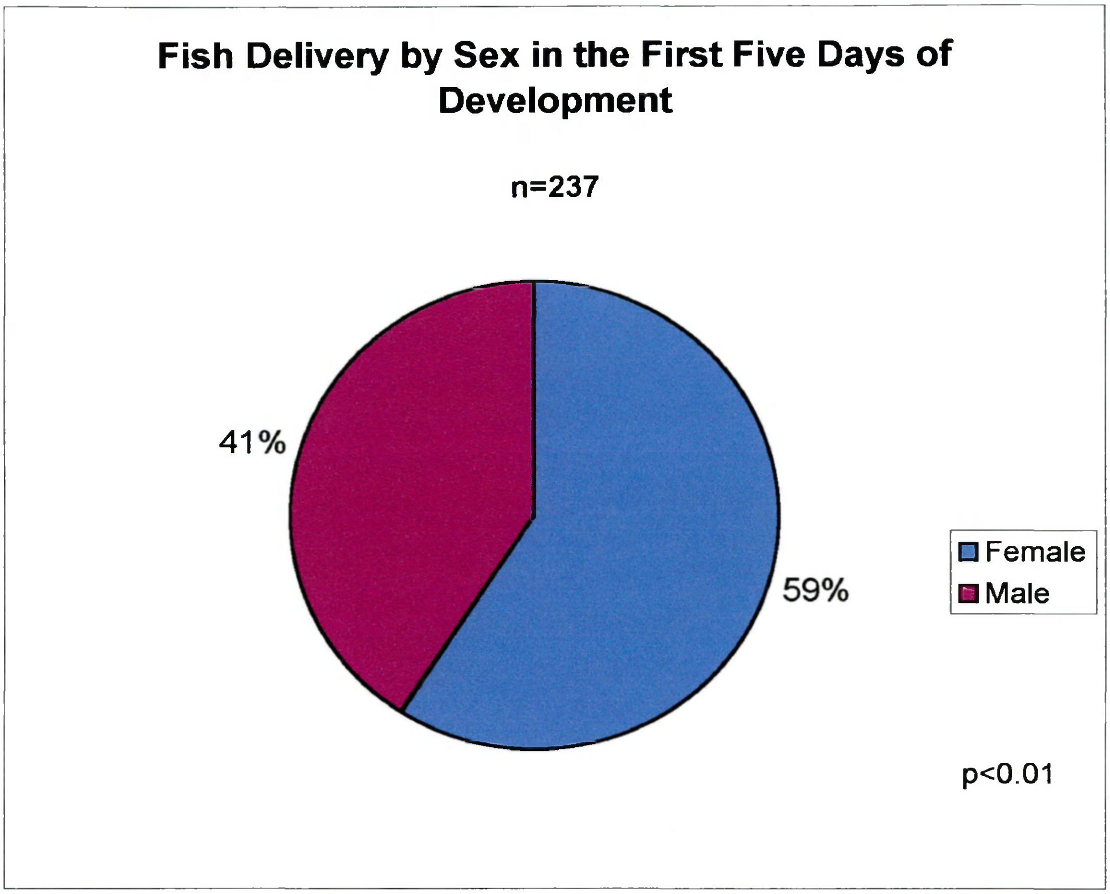

Figure 7 – **Sex of adult delivering prey to nest over the entire 24-hour cycle during the first five days of the chicks development. Difference between sexes was statistically significant at the p<0.01 level.**

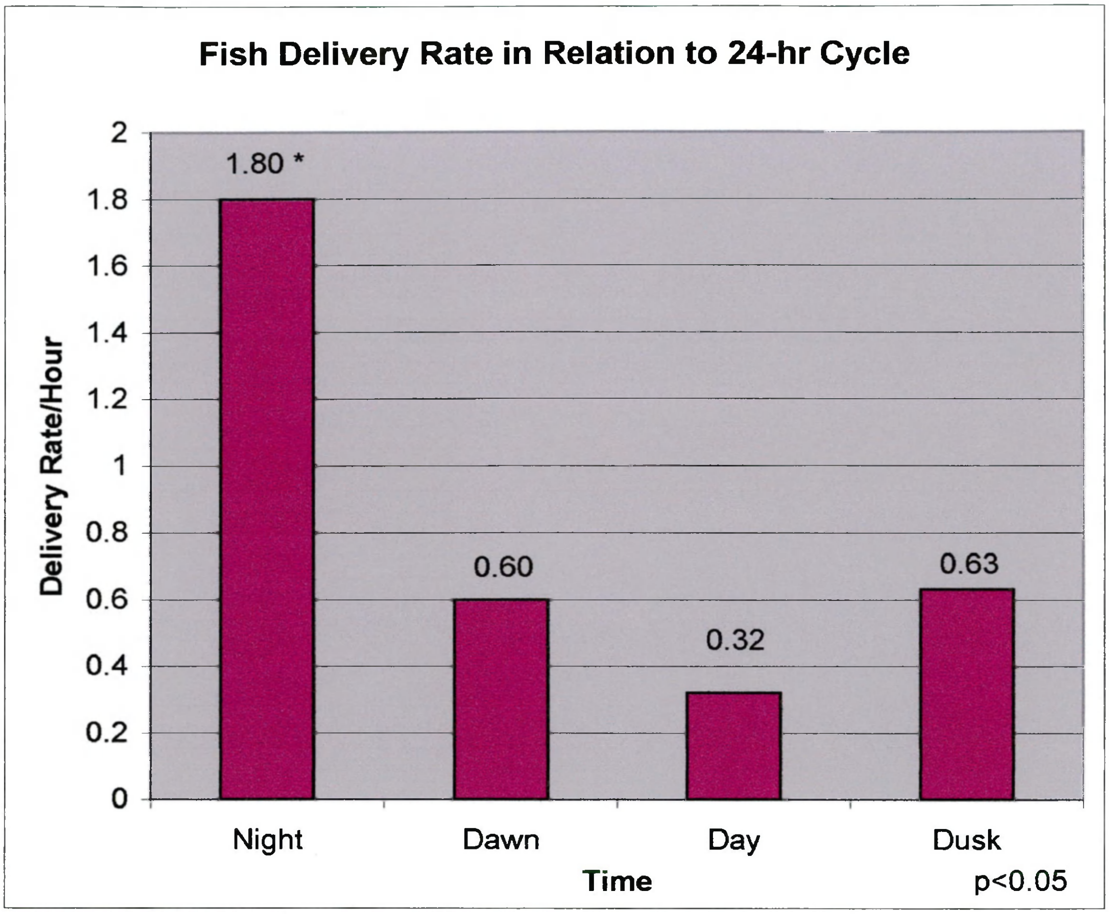

Figure 8 – **Fish delivery rate by both males and females over the entire 24-hour cycle during the entire life of the chick. Differences between time periods were statistically significant at a $p<0.05$ level.**

***= p< 0.05**
****= p< 0.01**
*****= p< 0.001**

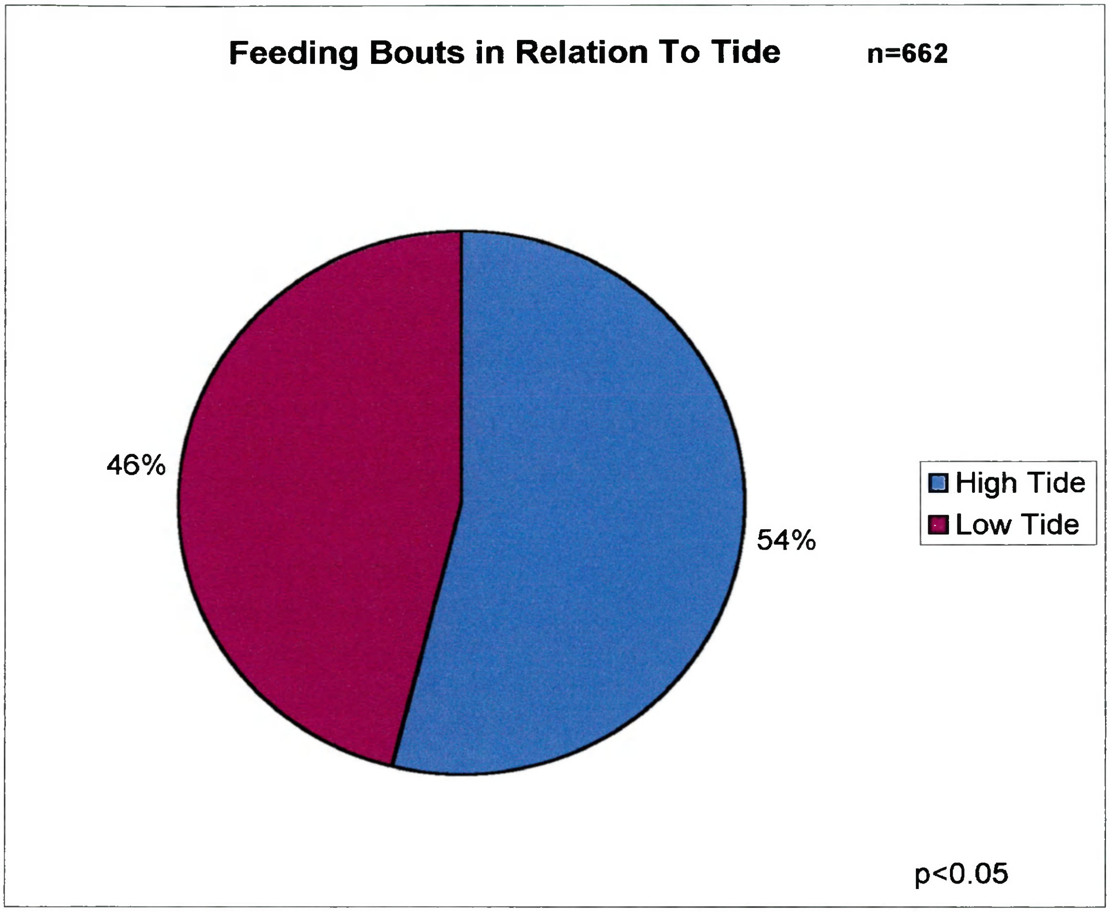

Figure 9 – **Tide at time of feeding bouts over the entire 24-hour cycle during the entire life of the chick. Difference in tide was statistically significant at $p<0.05$ level.**

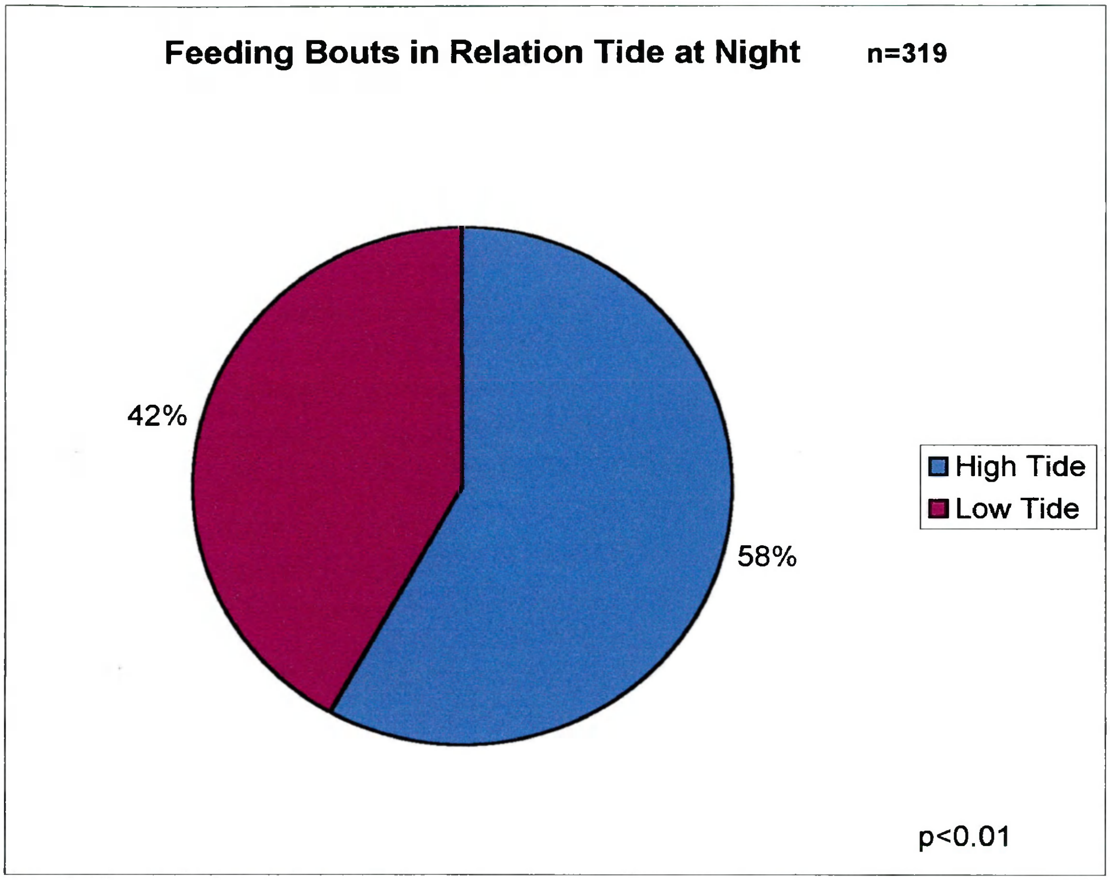

Figure 10 - Tide at time of feeding bouts over during the night during the entire life of the chick. Difference in tide at night was statistically significant at $p<0.01$ level.

Prey Availability/ Fate of Prey

During the 2001 nesting season 419 out of 662 fish were identified to genus and/or species from the video clips. Four types comprised 99% of the total fish observed (Figure 11). The fate of 569 prey items was determined using the same video recordings; chicks accepted 74% of the items brought to the nest and chicks rejected only 3% of all fish delivered to the nest (Figure 12). The fish most likely to be rejected by chicks was Needlefish (Figure 13; n=384, Chi-Square Test, $X^2=18.5$, df=3, $p<0.001$). Fish were most likely to be rejected within the first 5 days of a chick's development (Figure 14, n=18, Chi-Square test, $X^2=7.6$, df=2, $p<0.05$). The composition of the diet appeared to change over the chick's development. For example, the percentage of Bay Anchovy in a chick's diet decreased over time, while the percentage of Needlefish increased (Figure 15).

Feeding Rates

There was no significant difference in feeding rate between nests that fledged 0, 1 or 2 chicks per nest (Figure 16; n=20, Kruskal-Wallis, $X^2=1.7$, df=2, $p>0.4$). Even when comparing the first five days of development, the feeding rate of chicks that fledged was not significantly higher than those that did not survive (Figure 17; n=20 chicks, Mann-Whitney =25.0, $p>0.1$).

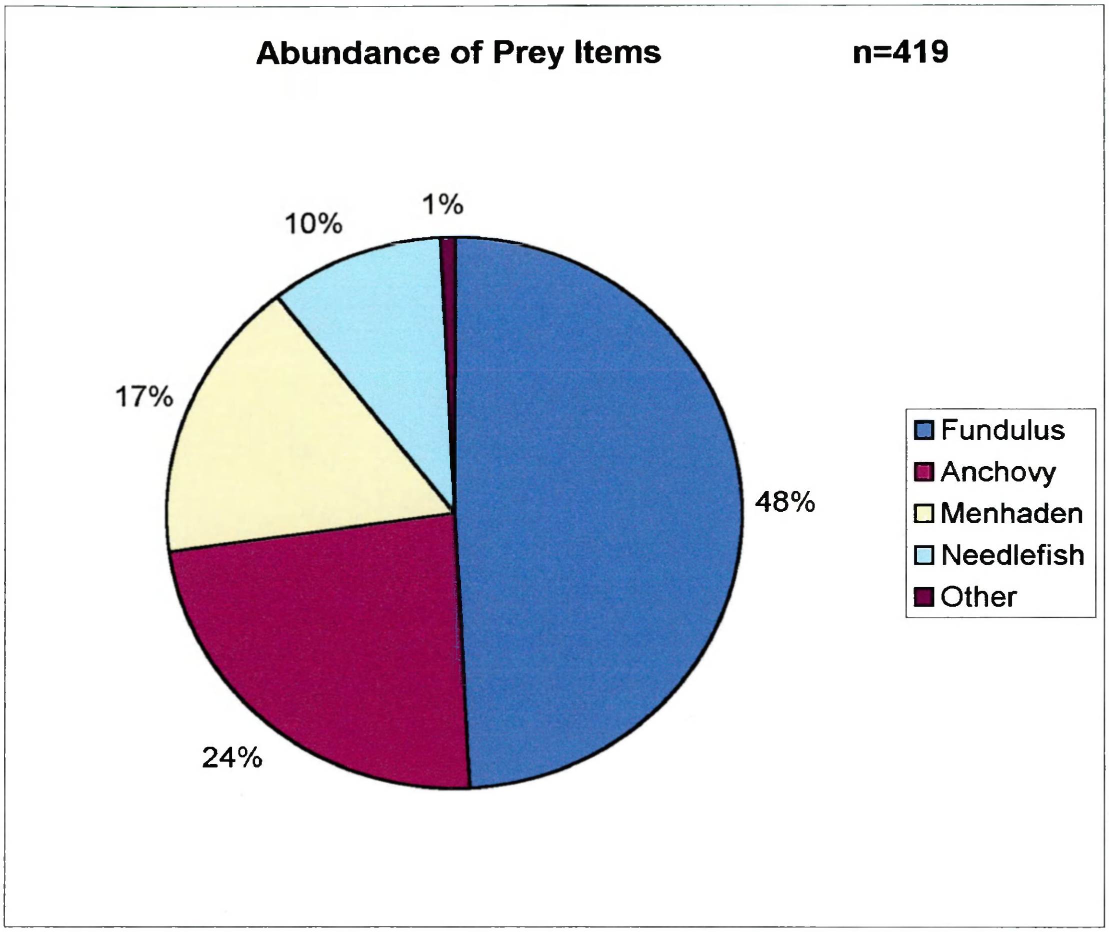

Figure 11 – **Abundance of prey items delivered to nest over the entire 24-hour cycle during the entire life of the chick. Items were identified by video surveillance and identified to species when possible.**

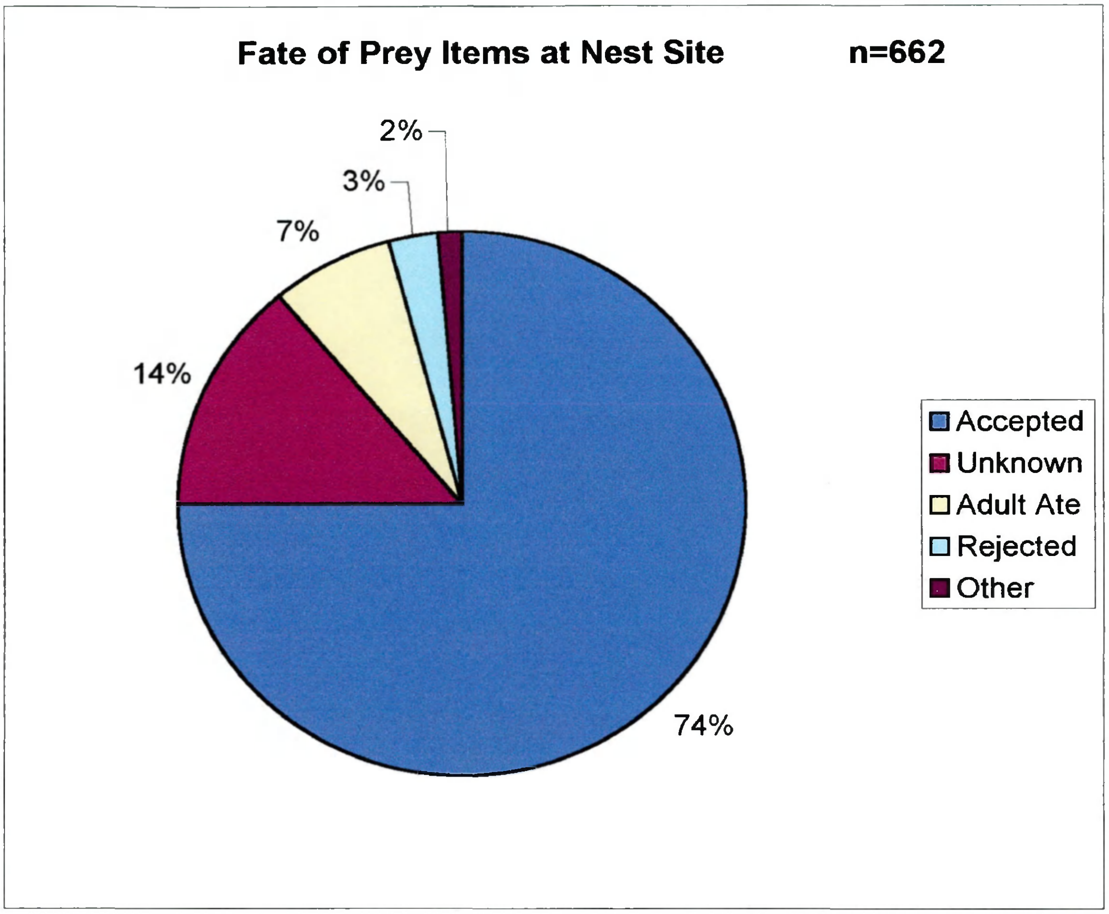

Figure 12 – **Fate of prey items delivered to nest over the entire 24-hour cycle during the entire life of the chick.**

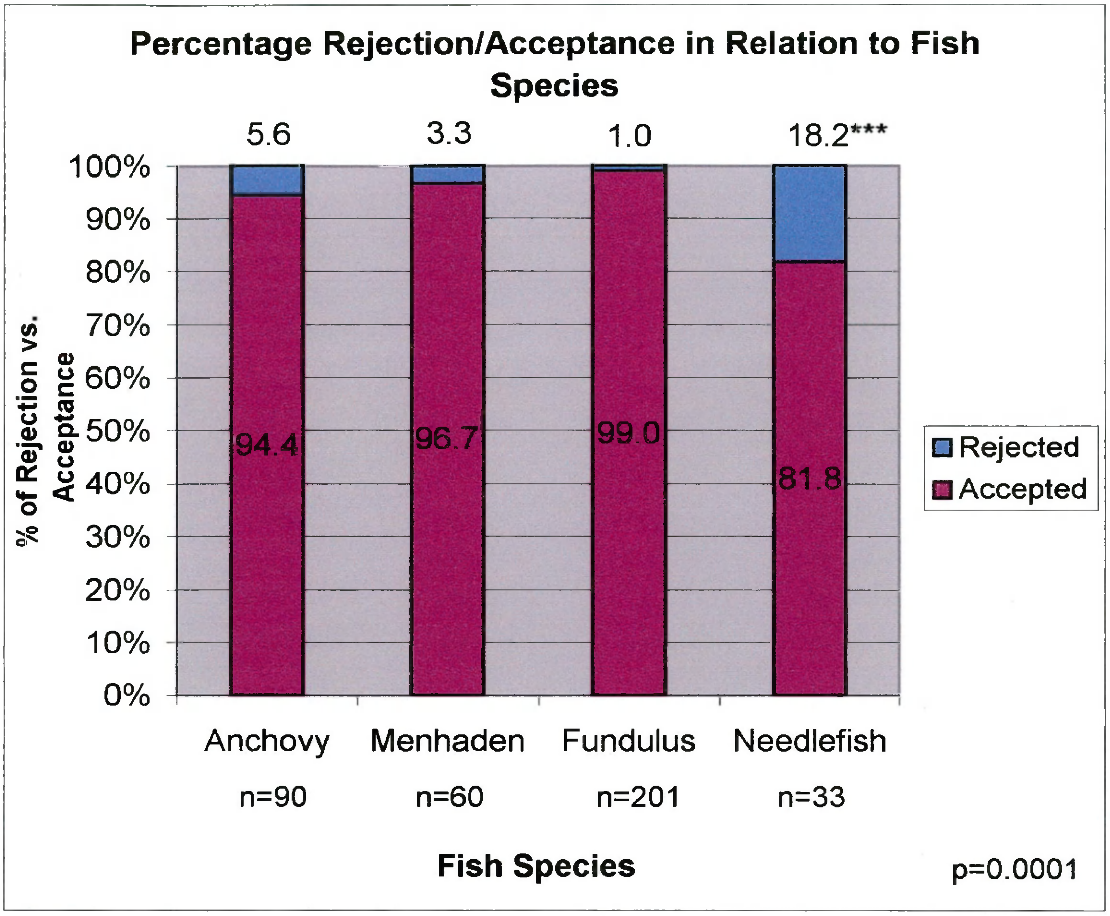

Figure 13 - Rejection/accpetance by fish species of fish delivered to nest over the entire 24-hour cycle during the entire life of the chick. Differences in rejection/acceptance rates were statistically significant at p<0.001 level.

***= p< 0.05**
****= p< 0.01**
*****= p< 0.001**
******=p<0.0001**

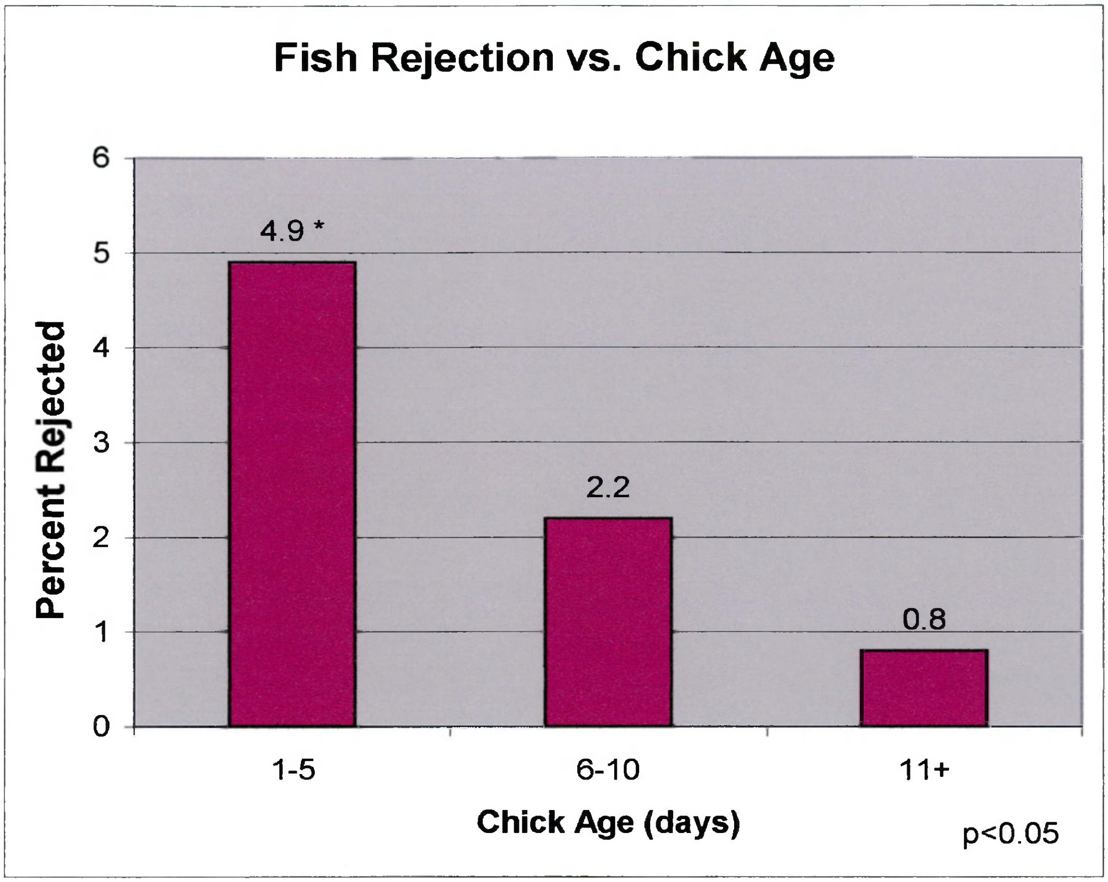

Figure 14 – Percent of fish rejected over the the entire 24-hour cycle during the entire life of the chick. Differences in frequencies of fish rejection were statistically significant at $p<0.05$ level.

***= p< 0.05**
****= p< 0.01**
*****= p< 0.001**
******=p<0.0001**

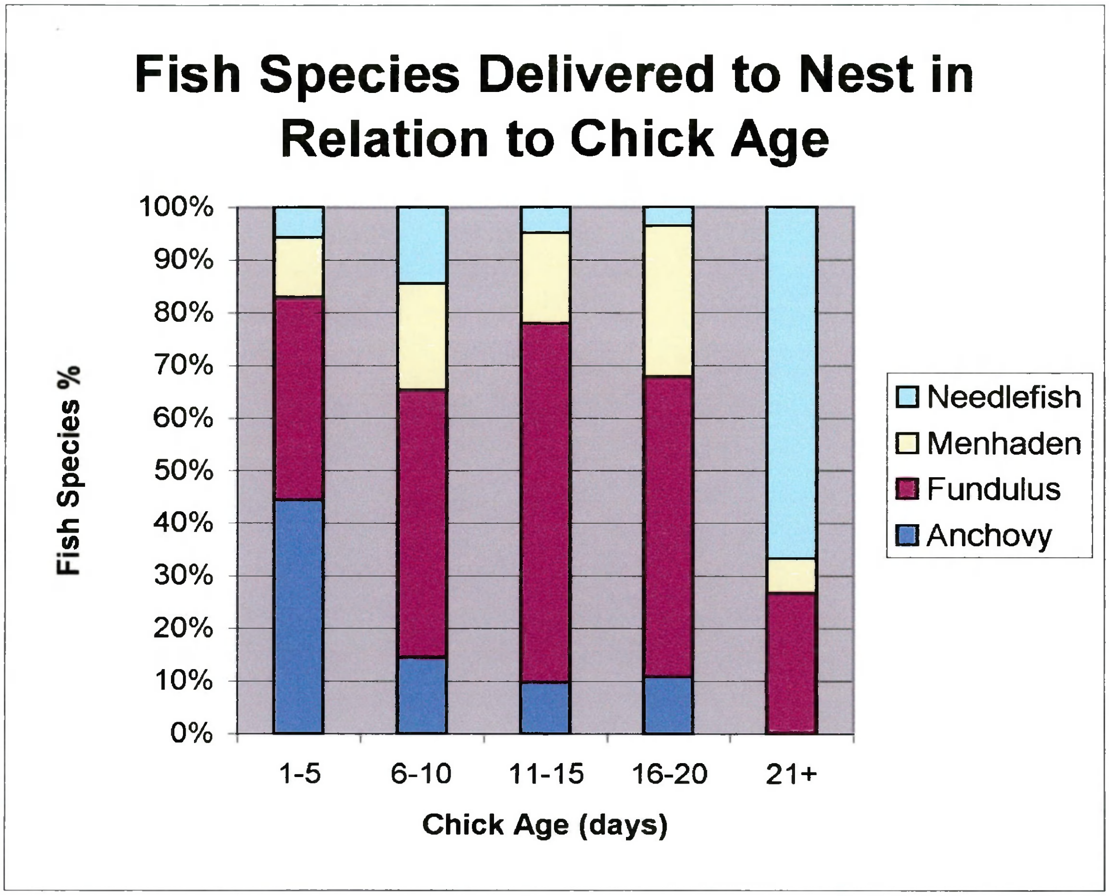

Figure 15 – **Fish species delivered to nest over the entire 24-hour cycle during the entire life of the chick.**

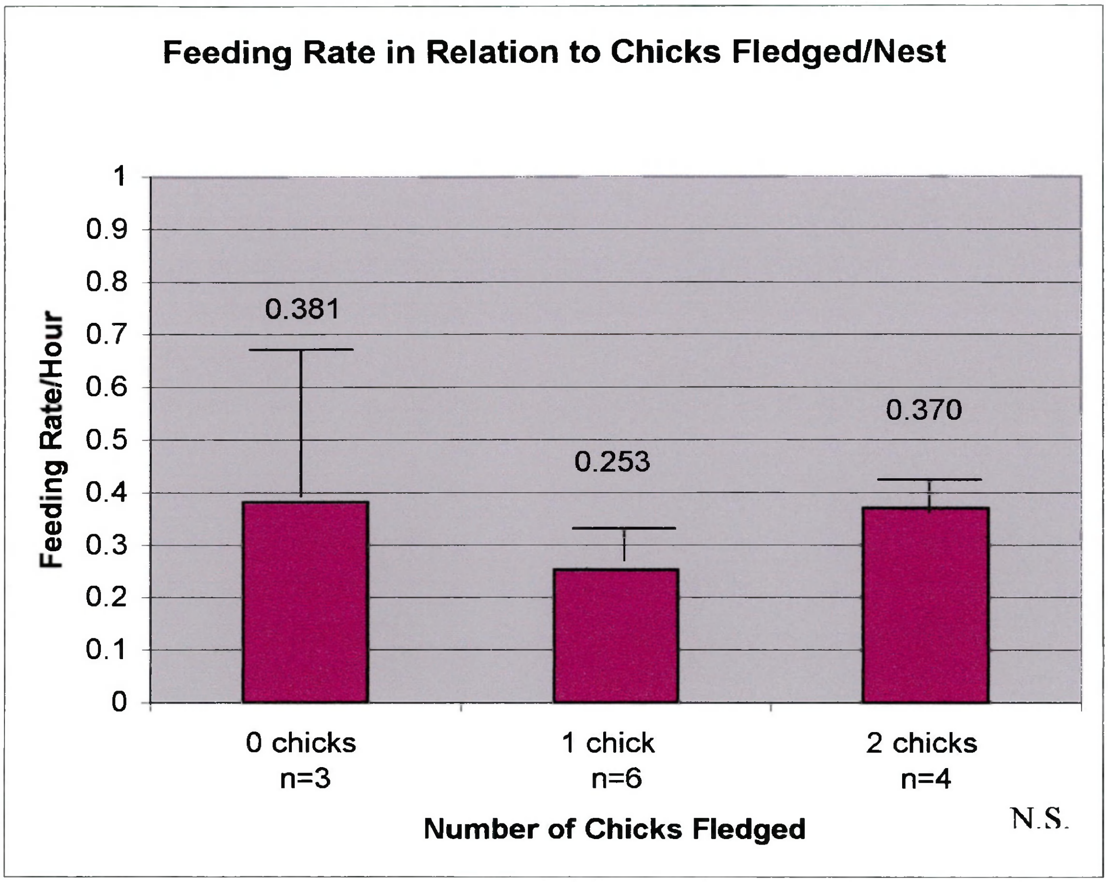

Figure 16 – Feeding rate of chicks in relation to the number of chicks fledged within the nest over the entire 24-hour cycle during the entire life of the chick. Differences in feeding rates were not statistically significant.

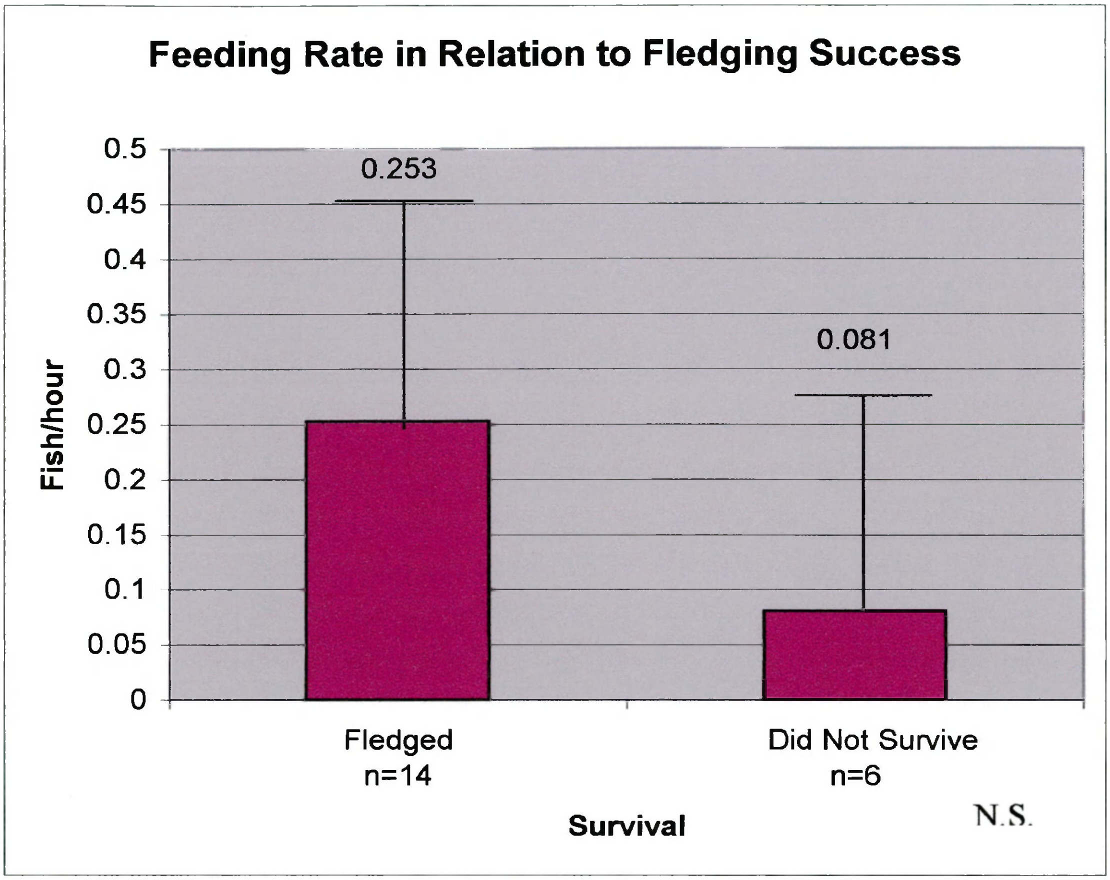

Figure 17 - Feeding rate of chicks in relation to survivorship over the entire 24-hour cycle during the entire life of the chick. Difference in feeding rate was not statistically significant.

Prey Length and Biomass

The upper mandible of both males and females was found to be the least variable (See Table 2) and for each sex this mandible was compared to prey items to determine prey length. The average length of the upper mandible of males was 84 mm, females 71 mm.

Males brought significantly larger prey items to the nest than females (Mann-Whitney $U=29420.5$, $p=0.0001$). The size of prey items brought by both males and females was significantly larger during the day (Figure 18; $n=576$, Mann-Whitney $U=35150.5$, $p<0.01$). The size of rejected fish was not significantly different than those that were accepted ($n=469$, Mann-Whitney $U=3186.5$, $p>0.1$; average size of rejected fish=80.5mm ± 49.1and accepted fish=59.9mm ± 29.5). Those fish which the parent flew away with were significantly smaller than all other fish brought to the nest ($n=8$, Chi Squared, $X^2=14.81$, $df=3$, $p<0.01$). Adults offered significantly smaller prey items to chicks aged 1-10 days than chicks 11+ days old (Figure 19; Kruskal-Wallis, $n=576$, $X^2=95.3$, $p<0.0001$)

There was no relationship between the amount of fish biomass intake/chick/hour and the number of chicks fledged within a nest (Figure 20; Kruskal-Wallis, $n=20$, $X^2=1.8$, $df = 2$, $p<0.4$).

Table 2 – Upper and Lower Mandible Measurements of Adult Black Skimmer Study Skins

	Upper Mandible Range (mm)	Upper Mandible Mean (mm)	Lower Mandible Range (mm)	Lower Mandible Mean (mm)
Female	65.30 - 90.28	71	74.12 - 120.24	87
Male	65.50 - 92.56	84	80.02 - 124.76	105

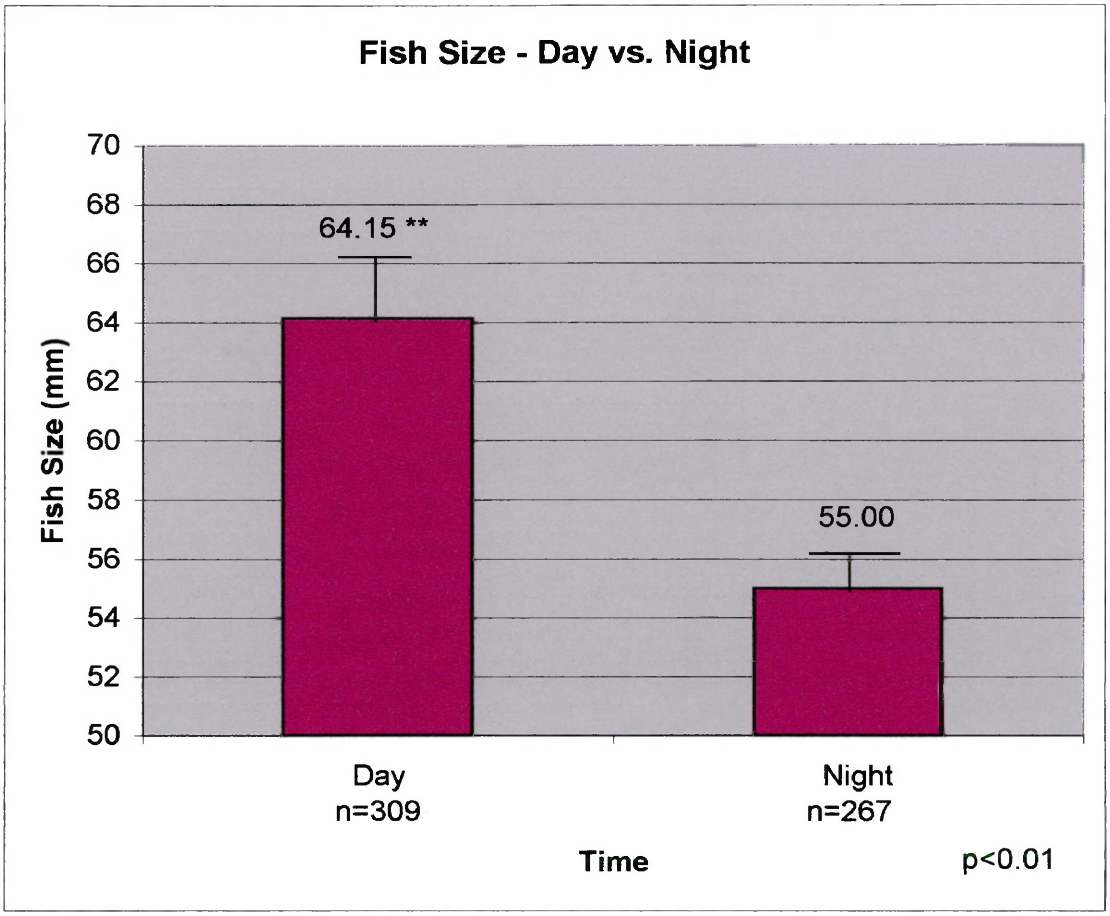

Figure 18 – **Size of fish delivered to nest over the entire 24-hour cycle during the entire life of the chick. Difference between day and night was statistically significant at the $p<0.01$ level.**

*= p< 0.05
**= p< 0.01
***= p< 0.001
****=p<0.0001

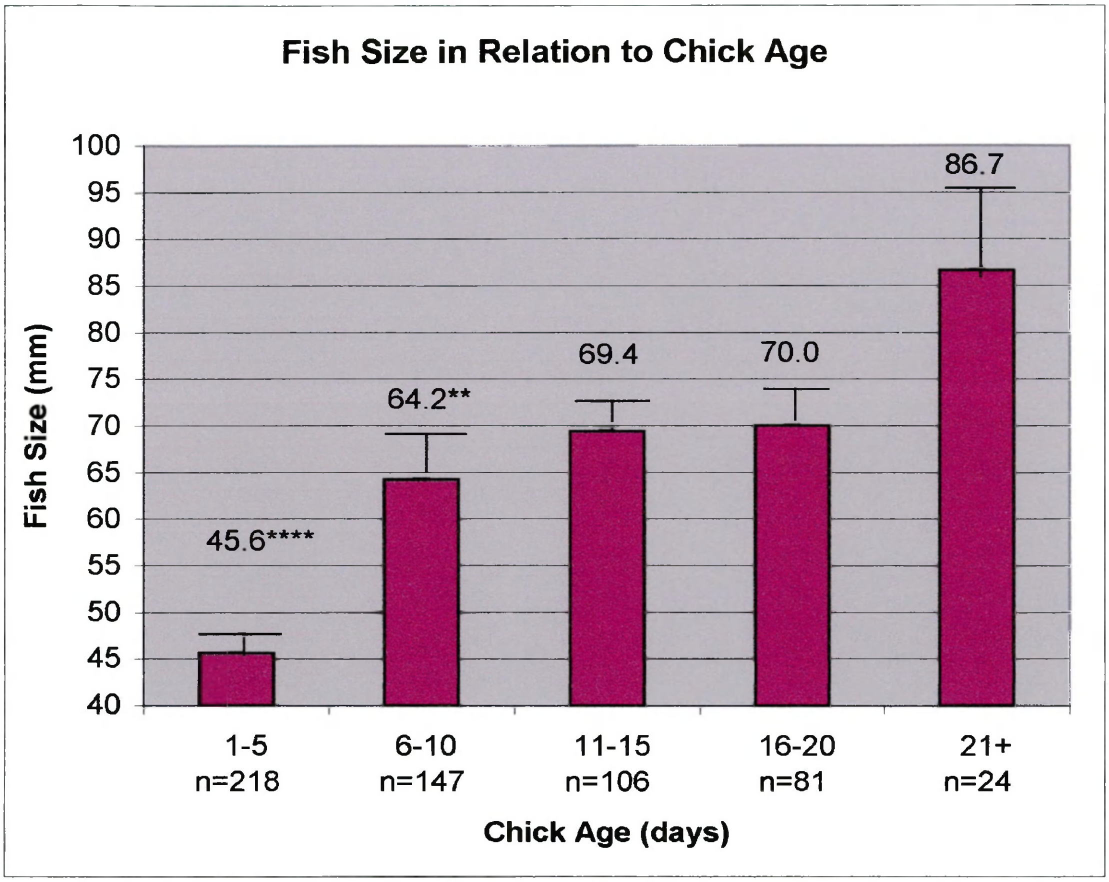

Figure 19 - Size of fish delivered to nest over the entire 24-hour cycle during the entire life of the chick. Differences between age classes were statistically significant.

***= p< 0.05**
****= p< 0.01**
*****= p< 0.001**
******=p<0.0001**

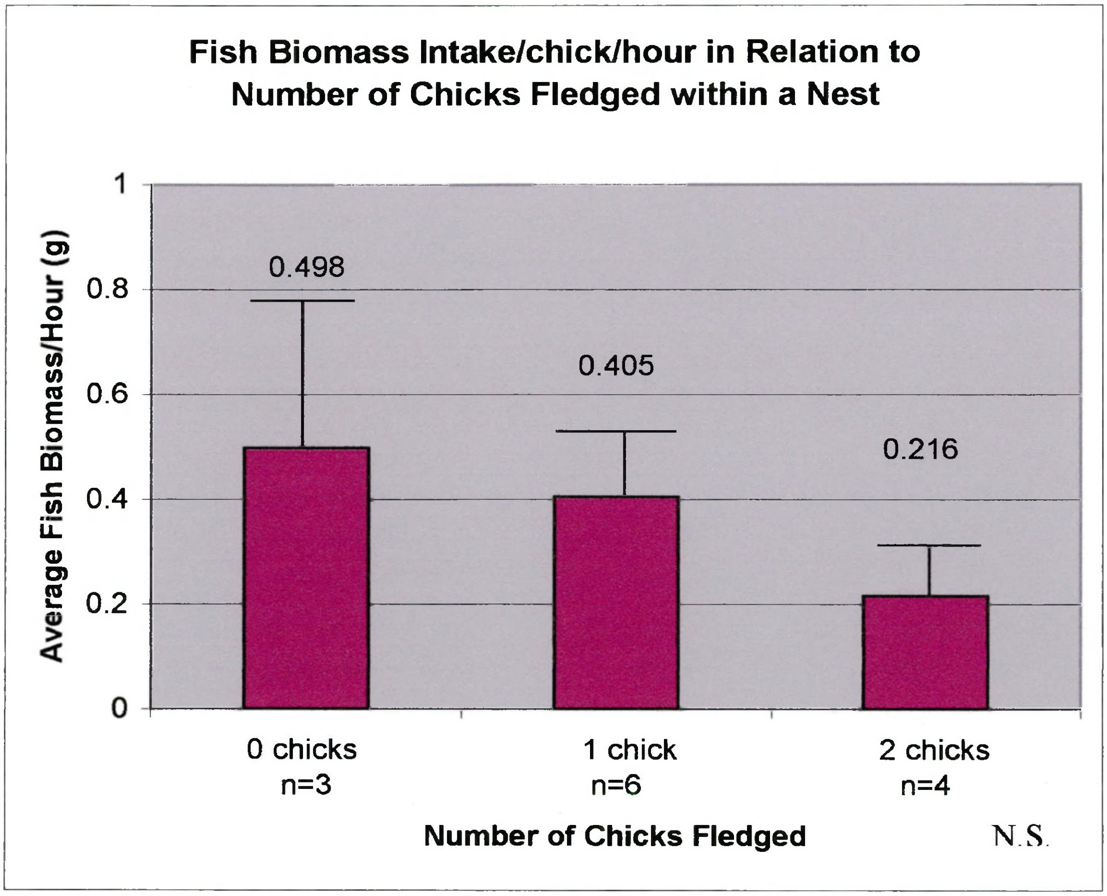

Figure 20 - **Biomass of fish delivered to nest in relation to the number of chicks fledged within the nest over the entire 24-hour cycle during the entire life of the chick. Differences in biomasses were not statistically significant.**

Productivity

The first Black Skimmer nest with egg was observed 11 May 2001. Skimmers nested with approximately 2,500 pairs of Common Terns (*Sterna hirundo*), 500 pairs of Laughing Gulls (*Larus atricilla*), 10 pairs of Herring Gulls (*Larus argentatus*), and 5 pairs of gull-billed terns (*Gelichelidon nilotica*). For Black Skimmers the number of nests, mean clutch size, hatching success, nest success, and number of young leaving nest were all lower than the mean for the colony in 1998 (Table 3). The nest success for the pre-fledging period was higher than the mean for the colony in 1998 (Table 3), but a significantly higher mortality rate occurred within the first 10 days of a chick's development (Figure 21; n=42, Chi-Square, X^2=29.429, df=3, p=0.0001).

Three nests with a total of five eggs were lost due to flooding from a rainstorm in video plots. Chick predation by Laughing Gulls was only observed once in video plots. While egg predation by Ruddy Turnstones (*Arenaria interpres*) was not directly observed in the study plots, the birds were detected moving throughout the entire nesting area. Possible predation by turnstones was not quantified during this study. Turnstones destroy eggs by making a small puncture or hairline fracture. Laughing Gulls tend to destroy the entire egg, masking the signs of turnstone predation. One case of conspecific predation was observed in the colony.

Table 3 – Reproductive Success for 1998 and 2001 Using the Mayfield Method (Mayfield 1961; Mayfield 1975)

Year	# of nests	Incub. Period (A)[a]	Pre-fledg. Period (B)[a]	Nest Success (AxB)	Hatch Success (C)[b]	Chick Success (D)[c]	Egg Success (AxBxCxD)	Mean Clutch Size (E)	Estimated young leaving nest (AxBxCxDxE)
1998	252	0.87	0.43	0.37	0.78	0.54	0.16	2.92	0.47
2001	109	0.49	0.63	0.31	0.75	0.23	0.05	2.48	0.13

a. Nest success, the probability that at least one egg or young survived for a given period (hatch – 21 days, fledge – 21 days)
b. The probability of an egg hatching, given that the nest was successful.
c. The probability of young living to 21 days given that the nest was successful.

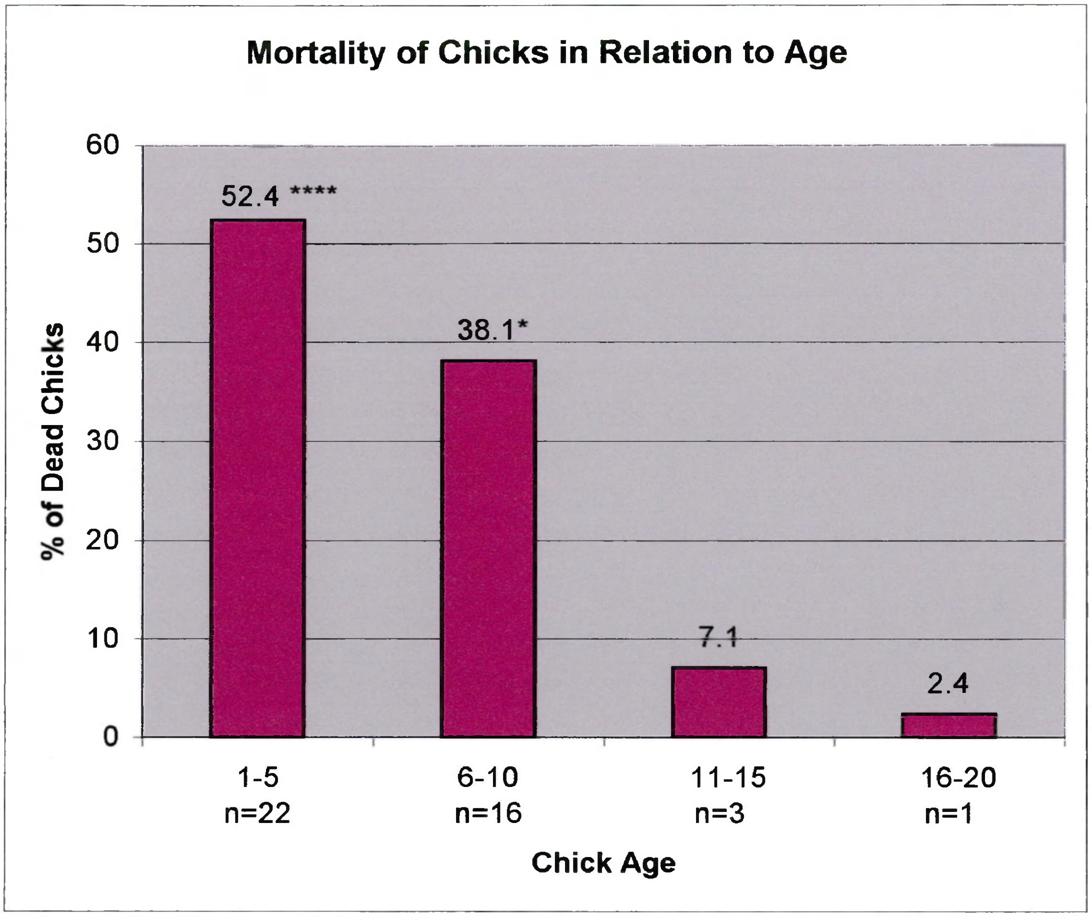

Figure 21 – Age of chick at death. Differences in death rates were statistically significant.

*= p< 0.05
**= p< 0.01
***= p< 0.001
****=p<0.0001

DISCUSSION

Studies of Black Skimmer prey rejection and selection are few (Erwin 1977; Quinn 1990). A study in the region, the Eastern Shore of Virginia, has cited *Fundulus* spp. and *Minidia* as the most abundant prey items selected by adults using visual observation (Erwin 1977). In contrast, Gordon (1999) determined that the most abundant prey item for Black Skimmers on the Hampton Roads Bridge-Tunnel, Norfolk Virginia, was needlefish. This difference in major prey items may indicate a shift in fish distributions in the region or may be due to the different collection techniques used. In this study, a remote camera system was developed to continuously record feeding bouts at selected nest sites from fledging to hatching. As in Gordon's 1999 study data collection was conducted from egg laying through the entire chick rearing stage of the birds.

Needlefish are generally larger in size than other potential prey items such as *Fundulus* spp., Atlantic Menhaden, and Bay Anchovy and therefore may be more likely to be rejected by chicks. Using prey composition and length, we tested the hypothesis that adult Black Skimmers selected prey items of a certain size or species that was inappropriate for the age of chick. To determine the appropriateness of size and species of prey items for chicks we tested two predictions: 1) fish that are rejected by chicks will be larger than accepted fish and 2) needlefish will be rejected more often than other prey items.

In addition the Birds of North America account for Black Skimmers lists several priorities for research within the species. Our unique video observation technique allowed us first to closely examine nocturnal behaviors; secondly, the system allowed for differentiation of sex of adult birds, fish size, and fish species. Therefore we decided to explore the following priorities in detail: 1) Nocturnal studies of feeding behavior and 2) Differential feeding by males and females (Gochfeld and Burger 1994).

Prey Composition

Within the species, data on the diet of adults and chicks is varied (Gochfeld and Burger 1994). This study yielded a detailed analysis, through the use of video monitoring, of prey composition and size over a 24-hour cycle from hatching to fledging. The diet of Black Skimmers at this site was similar to another study conducted on Fisherman's Island of the Eastern Shore of Virginia (Erwin 1977). *Fundulus* spp. was the top prey item in 2001, as in Erwin's 1977 study. In 2001 the Bay Anchovy was 2nd highest in abundance. In 1977 it was 3rd highest in abundance in Erwin's study.

In contrast, Gordon found in 1998 that the composition of prey species at this site consisted of primarily needlefish (54%) and menhaden (23%). Four additional fish species (Bay Anchovy, *Fundulus heteroclitus*, Northern Pipefish, and Hogchocker) comprised on average less than 7% each of the total sample size (Gordon 1999). This differed greatly from the composition of prey items determined during 2001: *Fundulus* spp. 48%, anchovy 24%, menhaden 17%, and needlefish 10%, other species 1%.

We determined that needlefish had the highest rejection rate by chicks during the 2001 breeding season. Due to this factor, Gordon's data collection method may have been biased toward needlefish. It is recommended that video observations of nests be used, when possible, in order to best determine the composition of prey items being brought to the nest.

Using data detailing local abundance of menhaden and needlefish within the region (Austin *et al.* 1998), Gordon concluded that fish declines might be driving skimmer declines. A further examination of the relation of local fish distributions and skimmer productivity is warranted due to the possibility of bias in skimmer prey sampling in Gordon's study.

<u>Fish that are rejected by chicks will be larger than accepted fish</u>

The fish rejection rate for Black Skimmers at the Hampton Roads Bridge-Tunnel was low, only 3%, which is similar to that of Quinn's (1990) study (1%). In 2001 a large proportion (65%) of the rejection occurred within the first five days after hatching. Courtney and Blokpoel's (1980) study of Common Terns also indicated that the fish rejection was highest in younger birds. Common tern chicks that were 1-4 days old rejected 42% of the fish brought to them, while 14-19 day old chicks rejected only 17% of what was brought to them.

From the results, no discernable difference between the size of rejected and accepted fish was detected, which is also similar to those of Quinn (1990). The average size of prey items was smaller within the first 5 days of a chick's development, $x = 46$mm ± 27.5, and rose steadily to $x = 87$mm $\pm$ 48.5 for chicks older than 21 days old. This suggests that adult skimmers select smaller prey items for younger chicks. These results are similar to other studies of terns and skimmers (Courtney and Blokepoel 1980; Erwin 1977). Therefore, we reject the hypothesis that adult skimmers selected prey of inappropriate size for the ages of their chicks.

Needlefish will be rejected more often than other prey items

Of all the prey species delivered to the nest (Fundulus spp., Bay Anchovy, Atlantic Menhaden, and Atlantic Needlefish), needlefish was rejected the most often, though it comprised only 10% of the chicks' total diet. Throughout development of the chick needlefish comprised only 6% of all the fish delivered to the chick within the first five days of its development and increased to 67% in chicks older than 21 days (although chicks can fly at approximately 21 days they will occasionally stay near the nest after that time). This is consistent with the overall data for size of fish brought to the nest, which showed that adults bring back progressively larger fish to the nest as a chick ages. Therefore, we reject the hypothesis that selected prey of inappropriate species for the ages of their chicks.

We also conclude that it is important to examine prey items over the entire nesting season, as prey size and species vary greatly. Identification of prey items during one day or one week of the nesting season may only give a "snapshot" view of prey species and/or prey size.

Differential Feeding by Males and Females

Skimmers are sexually dimorphic, with males having a larger body size and bill length, compared to females. Sexual dimorphism is traditionally attributed to differences in social mating systems (Owens and Hartley 1997). Skimmers are a monogamous species; hence this theory does not easily explain their dimorphism.

Differential selection of prey by adults may occur as a result of sexual selection for this differing body and bill size. Each copulation event begins with the male offering a fish to the female (fish presentation). The female will then choose whether or not to copulate with the male. The ability to catch larger fish may indicate better body condition; therefore, males may have evolved larger bills and body sizes in order to catch larger fish. Because of these factors, the size of delivered fish was compared to determine if there were any differences between the sexes.

Males brought back significantly larger fish to the nest than females throughout the nesting season. This suggests the possibility of differential selection of prey items between Black Skimmer males and females. Only one other published study has documented differential prey selection in Black Skimmers, with similar findings (Quinn 1990).

Nocturnal Observations of Foraging Behavior

Nocturnal feeding has been frequently reported in the literature though studies have never before been done on a continuous basis (Bent 1921; Erwin 1977; Burger and Gochfeld 1990). Using a camera with near-infrared sensitivity and low power IR illuminators we were able to determine that delivery rate of prey items was significantly higher during the night than during any other time period. It has been suggested that nocturnal foraging by adult skimmers may be due to a potential movement of fish to the water surface at night (Burger and Gochfeld 1990). It may also be possible that primarily tactile feeding Black Skimmers are more capable of foraging at night than other bird species in the colony and are utilizing this unique niche. Therefore, they would reduce the amount of competition for prey species.

In addition, it was determined that females delivered significantly more fish to the nest at night than during the day. Since females tend to deliver smaller fish to the nest than males, it was not surprising to find that the size of fish brought to the nest was smaller at night than during the day.

Colony Productivity

Productivity analysis has consistently been used at this site to determine the comparative nesting success of the colony. Therefore, the survivability during the incubation and chick stages was examined for the colony in 2001 and compared to data from Gordon's 1999 study. We were unable to compare survivability to that of nesting seasons previous to 1998 as a result of differing data analysis techniques.

Probability of survival during the incubation period (the probability that at least one egg survived to hatching) in 2001 (0.49) was lower than the survivability in 1998 (0.87) (Gordon 1999). Currently at this site avian predation and exposure (heavy rain, cooling, or heating) are among those variables that influence survivability during the incubation period. We believe the influx of more than 500 pairs of nesting Laughing Gulls in 2001 had a detrimental effect on success during the incubation period. We were unable to determine exact predation levels in 2001.

Though probability of survival during incubation was lower in 2001, hatching success (the probability of an egg hatching, given that the nest was successful) was similar in the two years, 0.78 and 0.75 respectively. This level of hatching success is relatively high compared to other East Coast populations (0.17-0.88). Nests that were destroyed before hatching was possible were not included. Since Laughing Gulls will generally destroy entire nests, hatching success is not influenced by this type of avian predation when compared to survival through incubation.

Chick success (The probability of chicks living to 21 days given that the eggs hatched) was lower in 2001 (0.23) than 1998 (0.54). Since avian predation was almost nonexistent on young in 1998, Gordon (1999) suggested that reproductive success was limited by food availability. To determine if the lower chick success in 2001 was due to a lower feeding rate the overall fish delivery rates were compared between 1998 and 2001. The comparison of fish delivery rates between 1998 and 2001 shows a similar rate in both years, 0.18 fish/chick/hour and 0.17 fish/chick/hour respectively. Therefore fish delivery rate does not explain lower survival of chicks in 2001.

Also, there was no difference between the feeding rates, during the first five days of development, for chicks that fledged versus those that did not. The actual biomass intake could vary greatly between chicks, depending on differing sizes of delivered fish (i.e., it is possible that fish are delivered to the nest, but skimmer chicks are not ingesting adequate biomass to survive). The biomass intake/chick/hour and feeding rate was calculated for each nest to determine if there was a sufficient food supply for survival to fledging. No significant difference in the biomass intake/chick/hour between nests that fledged 0, 1 or 2 chicks. In this study in 2001 feeding rate and biomass intake did not reliably predict the survival of chicks.

Along with feeding rate and biomass intake, predation is another factor known to affect chick success. During 1998 predation on skimmer chicks was almost nonexistent (Gordon 1999). In 2001, Laughing Gulls, known avian predators, dramatically increased in the colony to more than 500 nesting pairs. During any visitations to the colony all the birds in the colony flew away from their nests. Laughing Gulls were usually the first birds to re-enter a site after a disturbance, followed by Common Terns, and finally Black Skimmers. When Laughing Gulls returned to the colony, chicks were very vulnerable to predation. To ameliorate this problem, the number of visits to the colony was decreased from 6 times per week in 1998 to once per week in 2001. Avian predation may have led to a decreased chick survival in 2001. Further studies should be conducted to examine predation pressures at this site.

CONCLUSIONS

1. In Gordon's study (1999), prey species at this site consisted of primarily needlefish and menhaden. This differed greatly from the composition of prey items determined during 2001, when *Fundulus spp.* and anchovy were the top prey items.
2. Overall rejection rate of prey items was low; chicks rejected only 3% of all fish delivered to the nest.
3. The size of rejected fish was not significantly different from that of accepted fish. The size of prey items was found to be smaller within the first 5 days of a chick's development. Of all the prey species delivered to the nest, needlefish were rejected the most often, though needlefish comprised only 5% of all the fish delivered to the chick within the first five days of its development, when most of the rejection occurred. Therefore, we do not believe that adults selected prey of inappropriate size or species for the age of chicks.
4. There was no significant difference in the biomass intake/chick/hour between nests that fledged 0, 1 or 2 chicks. Also, There was no significant difference between feeding rate during the first five days of development and the survival of chicks. We conclude that feeding rate and biomass intake did not easily predict the survivability of chicks in 2001.
5. Males brought back significantly larger fish to the nest than females, suggesting differential prey selection by males and females.

6. In relation to time, delivery rate of prey items was significantly higher during the night than during any other time period and females delivered more fish to the nest than males at night.

7. Survival during the incubation period was lower in 2001 (0.49) than in 1998 (0.87). We believe the influx of more than 500 pairs of nesting Laughing Gulls in 2001 may have had a detrimental effect on nesting success by means of egg predation during the incubation period.

8. Chick Success was lower in 2001 (0.23) than 1998 (0.54). We suggest that the additional predation pressure of 500 nesting Laughing Gulls may have led to the decrease in skimmer chick success during the 2001 breeding season.

FUTURE STUDIES

Our recommendations for future studies include investigation of foraging behavior, human disturbance, nest attendance, predation, and chick prey handling. Important foraging areas have not yet been identified at this site. Attachment of radio transmitters to birds could be used to monitor movement of adult skimmers. Detailed information is needed about the location and habitat structure of foraging areas.

We feel that the camera set-up used in the 2001 breeding season is ideal to examine the effects of human disturbance in colonial nesting birds. Currently, there is a great concern by waterbird researchers regarding the effect of human disturbance on colonial nesting birds. One of the recommendations of the Colonial Waterbird Conservation Plan is to look at the effects of all types of human disturbance on colonies. Two identical cameras could be placed at opposite ends of the colony. Researchers would enter one of the sites periodically; the other would not be entered over the entire nesting season. Factors such as reproductive success, food delivery, and nest attendance could be monitored using only data from the recorded video and compared between disturbed and undisturbed sites.

The arrival of Laughing Gulls at the island in 1999 lends the site to studies of invasion of nesting Laughing Gulls into previously avian predator-free areas. A detailed study could determine the exact extent of egg and chick predation by Laughing Gulls.

Finally, data from existing tapes of the site could be used to examine chick prey handling. Skimmer chicks have rarely been reported to pick up fish from the ground (Gochfeld and Burger 1994). On the contrary, this behavior was observed often at the site, especially in chicks 5 days or older (unpublished data). Tapes could be screened to quantify this behavior.

MANAGEMENT RECOMMENDATIONS

The advantages of the video system used in this study were numerous. Although the camera system did take approximately a week to set up and adjust, once the system was in place there was little need to go into the area except for weekly nest counts of the entire colony. The equipment can be acquired within a week from Internet companies or local retailers at a reasonable cost. Cameras, VCR's, monitors, IR lights, and other equipment can be used multiple years. This defers initial start-up costs, which run about $3,000 for a single set-up.

When conventional power sources are not available at nesting sites, the system can be adapted with appropriate auxiliary power sources, e.g. battery power or solar panels. Temporary shelters (sheds, blinds, trailers, etc.) can be erected to house recording and controller equipment on sites that lack permanent buildings. The distance of shelters to nesting areas is relatively unlimited, depending only on the length of cable (cables can be spliced together to increase length).

Assets of this system are that the video-monitoring allowed us to 1) observe the colony continuously 2) collect nocturnal data 3) observe multiple nests at once 4) make detailed observations (fish species and size) 5) observe the colony without disturbing the birds. The data record obtained from the video observation is permanent and can be accessed by a number of researchers during the data analysis stage or in future years. In addition, it is a relatively non-biased data collection method, allowing the opportunity to look back at individual feeding bouts multiple times.

We recommend that habitat manipulation and augmentation continue at the site. Since vegetation has dramatically grown up on the island in the past 6 years we recommend spraying regimes to control the growth of vegetation. Highly vegetated areas are attractive to nesting laughing gulls; therefore reducing vegetation may succeed in decreasing the number of nesting Laughing Gulls in the future. We also need to closely monitor the population of nesting Laughing Gulls at the site.

Finally we recommend the continued use of barriers around nesting areas, posting of nesting sites, and closing off of nesting areas to vehicular traffic. These measures have greatly reduced the amount of chick mortality due to vehicular traffic.

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